Possible period of the design of Nakṣtras[1]

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Abstract

The Nakṣtras were designed to keep track of the moon's path in the night sky. No literature gives the exact position of these Nakṣtras but there are many stories associated with each Nakṣtra. They were also probably used for time keeping over days. There are a total of 27 Nakṣtras spanning the night sky and the Moon spends an average of one day (night) in each Nakṣtra. However, as per the present association of stars with these Nakṣtras, several of them are as far as 25º away from the ecliptic where as Moon travels only about 5º on either side of the ecliptic. The possibility that in the remote past the ecliptic could have been 25º north to the present is not likely. We are not sure when the Nakṣtras were originally identified or when and how many times they were altered. To understand when could be the Nakṣtras defined. We studied the sky pattern from 3500 BC to 2005 AD and realized that the Moon path was closest to the maximum number of Nakṣtras around 3000 BC. We therefore suggest that the Nakṣtras were defined around 3000 BC and that the current association of star like. Mṛgaśirā with Nakṣtra needs to be re-examined

Introduction

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The ancient Indian calendar dates back several thousand years and the relevant literature has been extensively collated in a major commentary called the *Indian Calendar*, by Sewell and Dikshit (1986). These Nakşatras are used to keep track of the path of the moon. Elsewhere Bhujle and Vahia (2006) have discussed the manner of calculation of tithis, which shows that its calculation was made independent of observation by some excellent analytical work of Varahmihira. Since then, the location of Moon in a particular Nakşatra is a point of interest only to sky watchers. However, in early times direct observations must have played a critical path in keeping track of the days of a month.

Indian Calendar is called *Pancāng*. Nakşatras play an important role in this calculation. The time, which the Moon requires to travel over the 27th part of the ecliptic, is called 'Nakşatra'. During the traversal of Moon around the Earth the Moon is close to some of the fixed stars. Twenty-seven groups of stars that fall on the path of the Moon are identified. In 27.3 days, that is, Moon's one sidereal revolution, Moon travels through 27 stars that were said to form the 27 *Nakşatras*. Hence, on an average Moon travels one Nakşatra everyday. The star, which is closest to the Moon on its path, is called Moon's *Nakşatra*. Note that the Sidereal period of the Moon (from Full/New moon to the next full/new moon is 29 days and the Lunar month is defined by this period. Hence in one Sidereal (normal) month, the moon will travel 27 Nakşatras and repeat two more. Approximately 12 sidereal months make a year. The twelve months were named after the stars at which full moon occurs and these are *Caitra*, *Vaishākha* Jyeşţha, Āşāḍha, Śravaṇ, Bhādrapadā, Aśvin, *Kārtik, Mārgaśīrş*, Puşya, *Māgha,* Phālgun. Typically alternate stars with some skips refer to month names and hence accommodate 27 stars corresponding to nearly 360 degrees motion of Sun in a solar year.

'Bharateeya Jyotishya shaastra' states that each *Nakṣtra* name corresponds to a group of stars called star mansions or Asterisms. The concept is that moon visits these mansions in his trajectory around earth.

In this paper we give the detailed analysis of the identification of the Nakṣtras. We make following assumptions to identify the Nakṣtras.

- Nakṣtras named by ancient Indians must have been clearly visible to the naked eye and hence brighter than 5 magnitudes.
- Nakṣtras should be close to the moon's path.

The names of Nakṣtras and their meanings are given in Table 1 below.

The earliest reference of the names of Nakṣtras appears in Yajurveda.

Identification of Nakṣtras

Table 2 gives the traditional Nakṣtras and the stars associated with them in modern catalogues (Mahajani 2005).

Table 1: Names of Nakştras common and from Atharva Veda and their meaning

Nakşatras	**Name in Atharva Veda (1)**	**Meaning (2)**	**Meaning (1)**
Aśvinī	Aśvayujau	Riding a horse, one whose presiding deity is Aśvinā	Two Horsemen
Bharanī (pl)	Bharanyas	Bearing, maintaining	Bearers
Kṛttikā (pl)	Kṛttikā s	Hyde, Skin, Bark of Bhūrja tree	Cutters (/), Knife(?)
Rohinī (pl)	Rohinī	Red one	Ruddy
Mṛgaśīrā	Mṛgaśīras	Animal head	Dear's head
Ārdrā	Ārdrā	Fresh, Damp, Tender	Moist
Punarvasu (dual)	Punarvasu	Restoring goods	Two that are good again
Pusya (Sidhya, Tisya)	Pusya	Nourishment	Auspicious, nourishing
Āśleśā (pl)	Āśleśās	Embracing, Entwining	Entwiners
Maghā (pl)	Maghās	Bounty, Wealth	Mighty ones
Pūrvā Phālgunī	Phālgunyāu		
Uttarā Phālgunī	-		
Hastā	Hastā	Hand	Hand
Cītrā (pl)	Cītrā	Bright, Variegated, Spotted	Brilliant
Svātī (pl), (Nistyā)	Svātī	Sun's wife (Nistyā - Outcast)	Sword
Vīśākhā (dual & pl)	Vīśākhe	Many branches	Two with spreading branches
Anurādhā	Anurādhā	Accomplished	Success
Jyeṣṭhā	Jyesṭhā	Senior most, Chief, Pre eminent, First	Ruddy, Eldest
Mūla	Mūla	Firmly fixed, Root	Two releasers, root
Pūrvāṣāḍhā	Pūrvāṣāḍhā		Un-subdued
Uttarāṣāḍhā	Uttarāṣāḍhā		
Śravaṇa	Śravaṇa	Ear	Lame, Ear
Dhaniṣṭhā (sing and pl)	Śravisthās	Wealthy	Most famous
Śatabhiśā	Śatabhiśaj	Many stars	Having 100 physicians
Pūrva Bhādrapadā	Prodyhapādā	Auspicious	Having Ox feet
Uttara Bhādrapadā		Feet	
Revatī	Revatī	Wealthy one, Shining one	Wealthy

(1) Pingree and Morrissey (1989), table 3
(2) Based on current understanding of these words Jamkehdkar (2006, private communication)

Table 2: Names of traditional Nakṣtras, Bayer Identity of the principal star of the group

Nakṣtras	**Principal star**	**Principal star (1)**
Aśvinī	β Arietis	β Arietis
Bharanī	41 Arietis	35 Arietis
Kṛttikā	η Tauri	η Taurus
Rohinī	α Tauri	α Tauri
Mṛgaśirā	λ Orionis	
Ārdrā	α Orionis	
Punarvasu	β Geminorum	
Pusya (Sidhya, Tisya)	δ Cancri	δ Cancri
Āślesā	zeta Hydra	
Maghā	α Leonis	α Leonis
Pūrvā Phālgunī	δ Leonis	
Uttarā Phālgunī	β Leonis	β Leonis
Hastā	δ Corvi	
Cītrā	α Virginis	
Svātī	α Bootis	
Viśākhā	α2 Librae	
Anurādhā	δ Scorpii	
Jyeṣṭhā	α Scorpii	
Mūla	λ Scorpii	
Pūrvāṣāḍhā	δ Sagittarii	
Uttarāṣāḍhā	σ Sagittarii	σ Sagittarii
Śravaṇa	α Aquilae	α Aquilae
Dhaniṣṭhā	β Delphini	
Śatabhiṣā	λ Aquarii	λ Aquarii
Pūrva Bhādrapadā	β Pegasi	
Uttara Bhādrapadā	γ Pegasi	
Revatī	η Piscium	ζ Piscium

(1) Pingree and Morrissey (1989), table 5

Path of the moon in the sky is very sensitive to various perturbations such as tides and the exact relative separation of Sun, Moon etc. In order to calculate the position of the moon accurately for a given instant, it is necessary to take in to account hundreds of periodic terms in moon's longitude, latitude and distance. Jean Meeus (1998), takes into account the most important periodic terms. The accuracy of the result is 10´´ in the longitude of the moon and 4´´ in its latitude for the period of ±50 years from the current era. We assume that the formula doesn't give more than 1º of error in the path of the moon when used backwards till 3500 BC.

The software programme Sky Map Pro (2001) includes these corrections and we have used it to generate the sky pattern for a given time. This program gives graphic view of the sky from 4713 BC to 9999 AD. The program takes into account the changes in coordinates of the stars due to precession of earth. The author of the program uses Jean Meeus' Astronomical Algorithms.

We determine the RA and Declination of the Nakṣtras and Moon around 3500 BC, 3250BC, 3100 BC, 3000 BC, 2750 BC, 2500 BC, 2200 BC, 2000 BC, 1500 BC, 1000 BC, 500 AD and 2000 AD. Table 1 gives names of the Nakṣtras and the principal star of the group. The figures below (1-8) give the RA and declination of Moon and Nakṣtras in different eras.

The Figures show the distribution of Nakṣtras. Svāti is excluded because it is about 25º away from the ecliptic now on either side of Sun's path on equinox day. The dotted line shows the moon's path for the year mentioned. The diamond shaped points are the Nakṣtras for which the best fit could be obtained close to Moon's path for the mentioned year. Due to precession, moon's orbit will drift along the x axis with the period of 18.6 years. The amplitude along the

declination axis will also change due to this and hence the best possible fit was obtained with +/-9 years around the year mentioned.

Figure 1: Best fit of Nakshatras and Moon's path around 3,500 BC

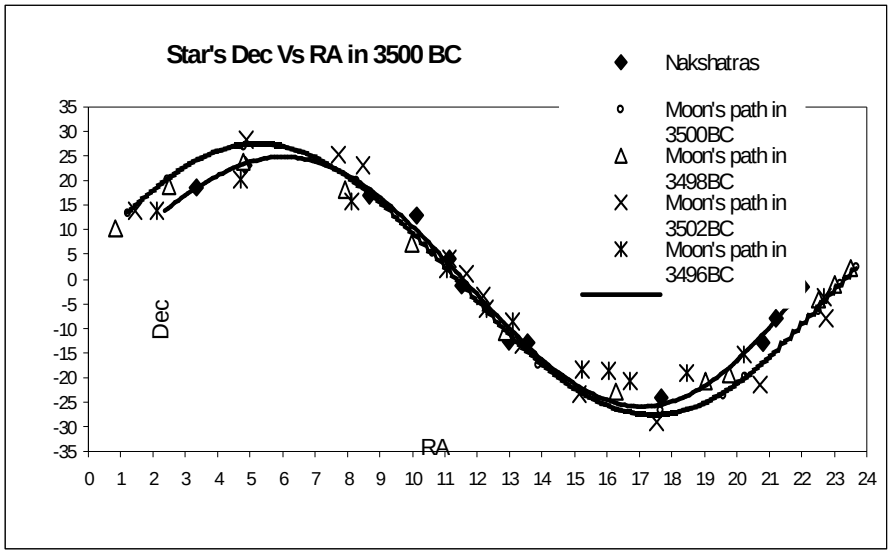


Figure 2: Best fit of Nakshatras and Moon's path around 3,000 BC

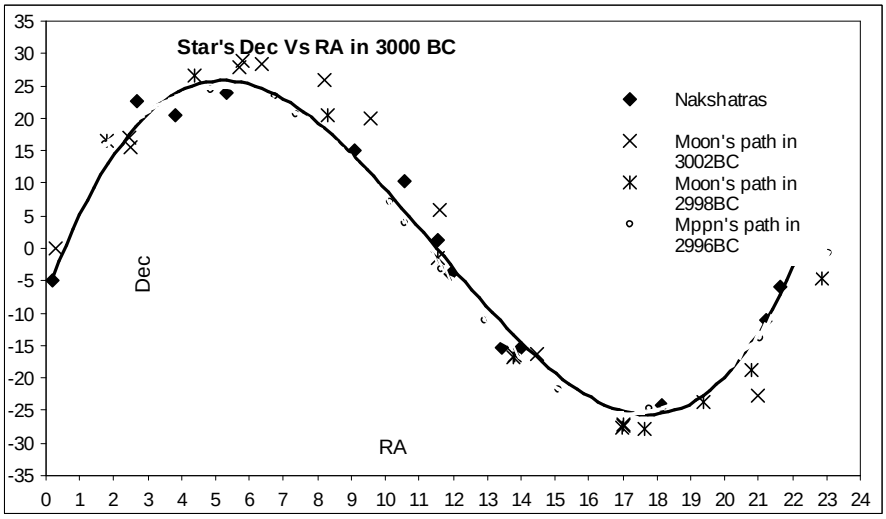


Figure 3: Best fit of Nakshatras and Moon's path around 2,500 BC

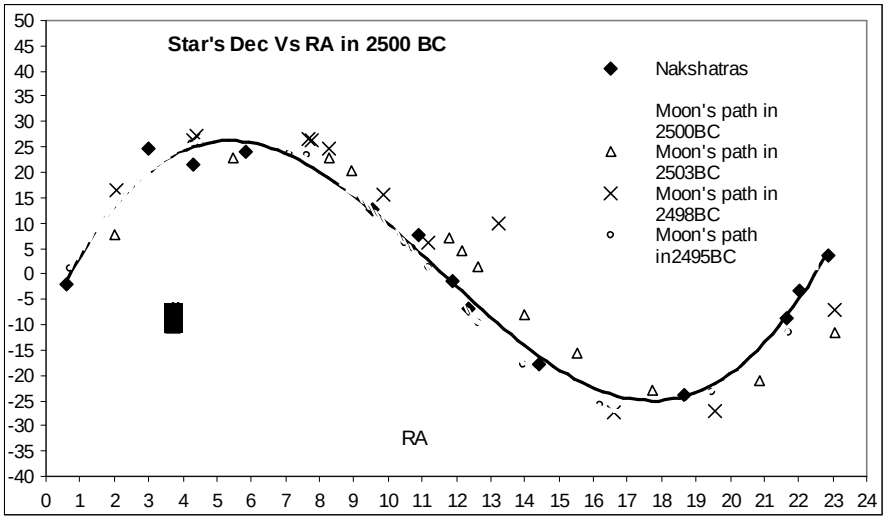


Figure 4: Best fit of Nakshatras and Moon's path around 2,000 BC

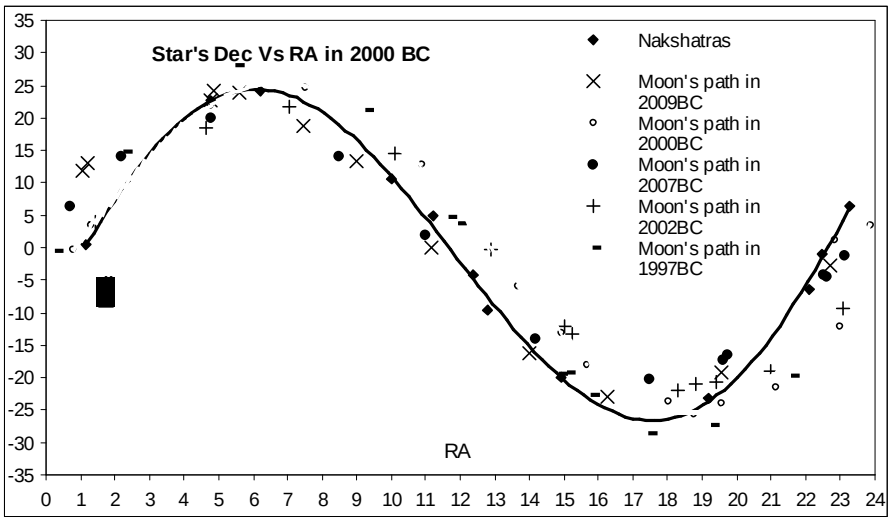


Figure 5: Best fit of Nakshatras and Moon's path around 1,500 BC

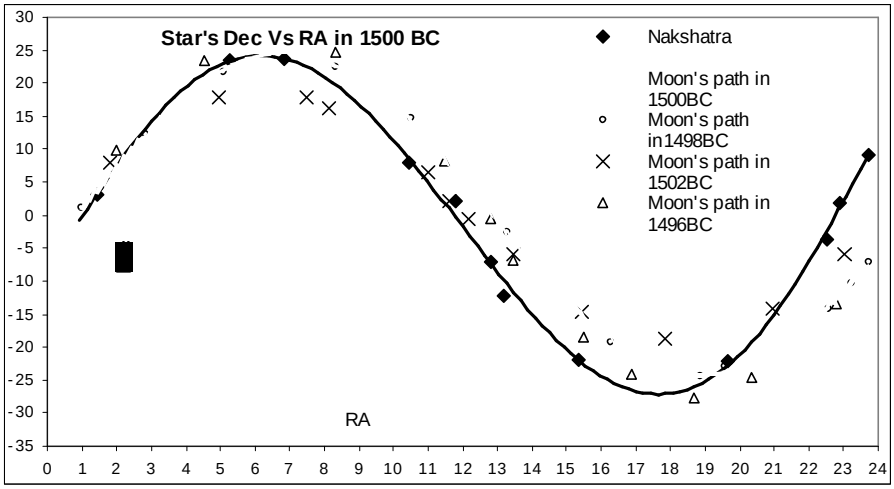


Figure 6: Best fit of Nakshatras and Moon's path around 1,000 BC

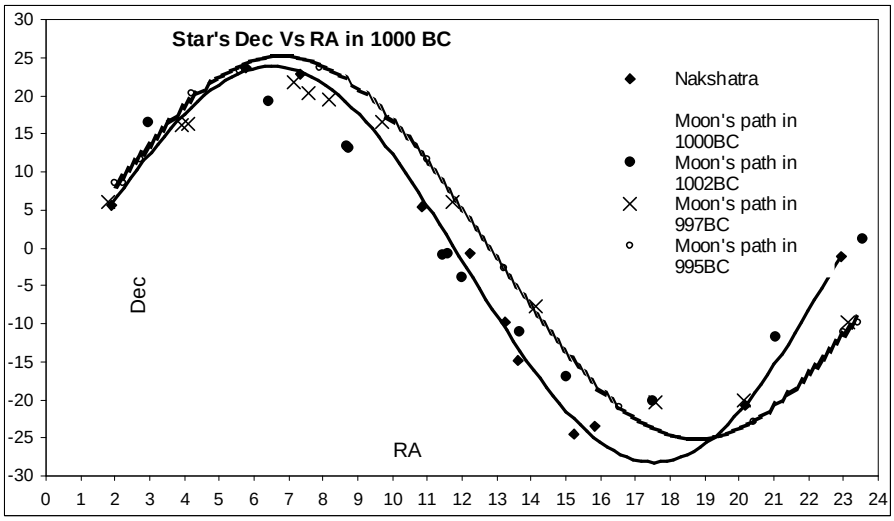


Figure 7 Best fit of Nakshatras and Moon's path around 500 AD

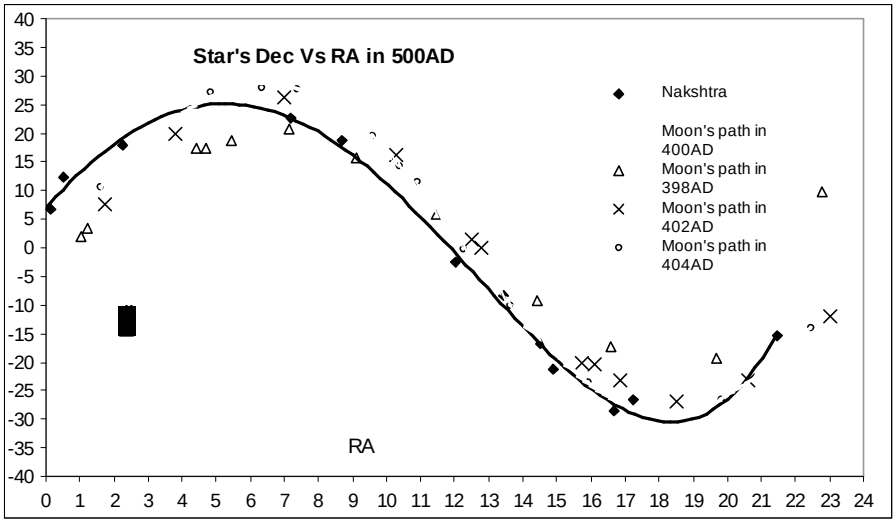
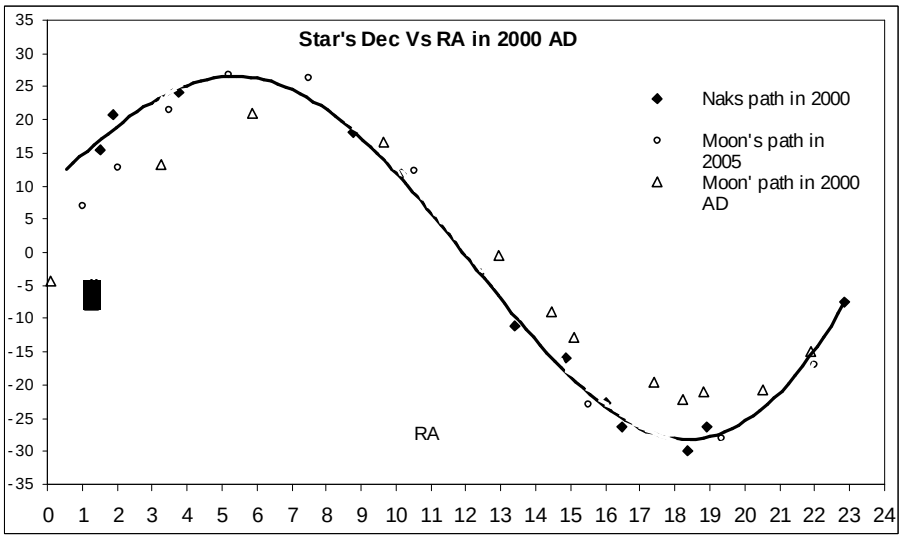


Figure 8: Best fit of Nakshatras and Moon's path around 2,000 AD



From the above figures 1 to 8 it can be seen that the best amplitude (declination) match of the Nakṣtras sine curve was around the year 3000 BC. The principal stars of the 9 Nakṣtras Pusya, Maghā, Cītrā, Viśākhā, Anurādhā, Jyeṣṭhā, Uttarāṣāḍhā, Śatabhiṣā and Revatī do always lie on the best-fit curve (solid line in above figures). So we can assume that the Nakṣtras were defined around 3000 BC and initially only 9 Nakṣtras were defined and then other 18 Nakṣtras were added to the list such that moon is in the vicinity of one Nakṣtra everyday in its revolution around the earth.

We calculated the difference in amplitude (Declination values) between Moon's path and Nakṣtras best-fit line for the same Right Ascension. We took about 5 readings at the peak position on both sides of the sine curve and found out the average of the absolute values of the readings. For example the table below gives the values of Moon's Dec and Nakṣtras Dec values at peak positions on both side of the sine curves.

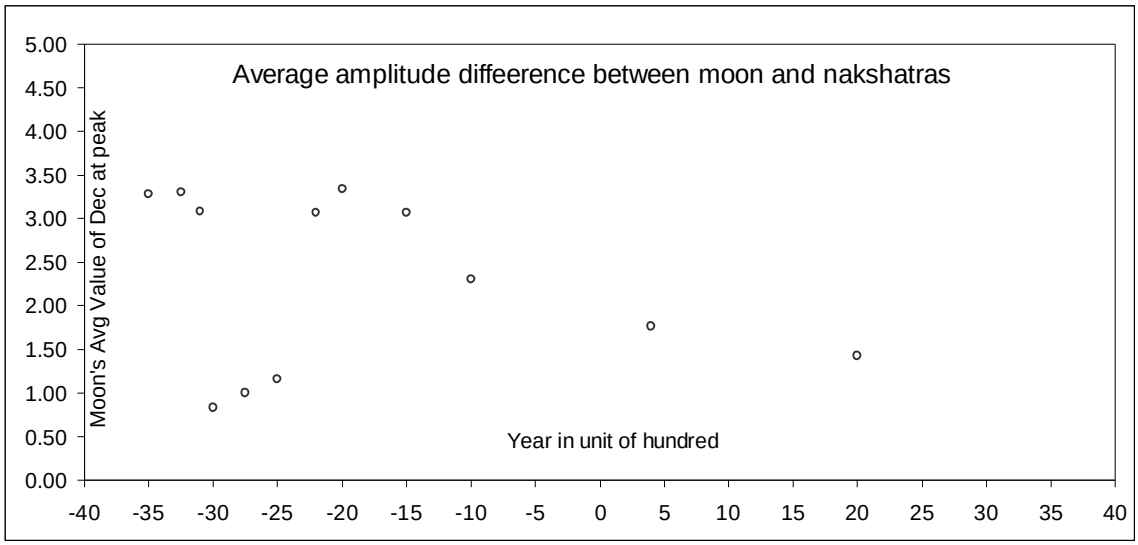
Table 3: Point of closest approach of Moon to traditional Nakṣtras.

RA Value	Moon's Dec	Nakṣtras Dec	Absolute difference
2	18	13	5
3	23	17	6
4	26	21	5
5	28	24	4
6	27	25	2
7	25	24	1
8	21	21	0
15	-21	-21	0
16	-26	-25	1
17	-27	-25	2
18	-28	-25	3
19	-25	-21	4
20	-21	-16	5
21	-16	-8	8

Average absolute difference = 3.285714

Similarly we calculated the average absolute difference for all other years. Figure 9 gives the plot of Mean value Vs Year

Figure 9: Average amplitude of difference between moon and Nakṣatras



It can be seen from the figure that the change in mean declination has changed significantly with time and was at its minimum around 3000 BC. We therefore suggest that the Nakṣtras were designed during this period.

However it is not clear why certain stars like Svāti, Mṛgaśirā, Ārdrā way out from the ecliptic, were chosen as Nakṣtras even though there were equally bright stars near the ecliptic. We give below a list of such stars, their Bayer identity and possible star candidate for the same Nakṣtra along with their magnitude and coordinates around 3000 BC. In table 4 we have listed the possible stars that are closer to the Moon's path than the conventional Nakṣtras and we suggest that these are more likely to be the correct Nakṣtras.

Table 4: Proposed change in the change in the star associated with a Nakşatra

Name of the Nakṣtra	Bayer Identity of the traditional star	Bayer Identity of other possible star	From (1)	Magnitude	Dec	RA
Mṛgaśīrā	λ Orionis			3.53	22.37	1.67
		β Tauri		1.68	12.73	1.1
			λ Orionis	3.66		
Ārdrā	α Orionis			0.58	-5.05	2.33
		γ Geminorum		2.02	7.25	2.45
			134 Auri	4.91		
Hastā	δ Corvi			2.93	6.1	8.7
		γ Virginis		3.45	21.43	8.72
			δ Corvi	3.11		
Svātī	α Bootis			0.16	45.7	10.63
		θ Centauri		2.05	-11.52	10.27
			22 Bootis	5.39		
Śravaṇa	α Aquilae			0.93	8.5	16.18
		β Capricorni		3.57	-13.36	16.07
			α Lyrae	0.89		
Dhaniṣṭhā	β Delphini			3.63	9.23	17.1
		δ Capricorni		2.86	-25.87	17.35
			α Delphinis	3.77		
Pūrva Bhādrapadā	α Pegasi			2.45	-2.9	19.33
		γ Piscium		3.75	-15	19.25
			α Pegasis	2.45	-2.9	19.33

(1)Pingree and Morrissey (1989), table 7

In this connection, we would like to mention the work of Pingree and Morrissey (1989), which has been particularly critical of the Indian astronomical claims insisting that the internal inconsistencies in the various literature indicate attempts to indigenise ideas that were borrowed from Babylonia and Greece. They have listed the complete set of inconsistencies between various observers over the millennia. Through an extensive analysis they show how the names and possible identifications drift from time to time. While conceding that the astronomical traditions are old in India, there are internal inconsistencies and concludes that the fit in year 425 AD is most consistent and hence the Nakṣtras were taken from Greece where Ptolemy created a catalogue in 425 AD.

We suggest that this is a misinterpretation of facts. First and foremost, the astronomical traditions and the names of Nakṣtras have existed from the Yajur Veda times itself as pointed out by Pingree and Morrissey (1989). We refer to Subarayappa and Sarma (1985) Astronomy, especially rise and zenith were integral part of the Vedic Traditions dating back to 2000 BC and earlier (Subarayappa and Sarma, 1985, page 1). Vedanga Jyotish, the oldest formal treatise on Astronomy dates back to 1400 BC (Subarayappa and Sarma, 1985, Appendix II), which predates the origin of astronomy in European traditions. Indeed Baity (1973) acknowledges that not only the Nakṣtras make a ready made appearance in Babylonia, their origin seems to be of proto Indians (Harappans) (see also Vahia, 2006). Also, from the period of Vedas itself, the overall sophistication of astronomy, as used in creating calendars is fairly complex (Subarayappa and Sarma, 1985, page 49). All this indicates that the astronomical traditions in India were very advanced well before they took roots in the west and are also more sophisticated than those in China (Baity, 1973). We however suggest that the confusions on which Pingree and Morrissey (1989) based their conclusion is due to the fact that the Indians did not keep any charts of sky which make long term comparisons difficult, requiring continuing

evaluation. Since the knowledge of sky is critical for navigation as well as rituals, the differences between records and direct observations can become obvious over relatively short periods and hence several corrections and re-interpretations must have been done. Hence the various contradictions pointed out by Pingree and Morrissey (1983) in fact indicate a rich and original astronomical tradition rather than borrowed knowledge, which is rarely continuously evaluated.

Conclusion

The Nakṣtras were probably identified around 3000 BC. Originally only 9 groups of stars were identified as Nakṣtras. The remaining 18 groups were added to the list later on so that moon is close to one Nakṣtra every night during its revolution of 27 days around the earth. However it is not clear why some of the stars were chosen as Moon's Nakṣtras even though other stars were closure to moon's path. We suggest that this apparently erroneous identification may be a problem with the association done later.

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